# ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY



First Partial Report On

PROJECT NO. 41 - Physiological Characteristics of the T25E1 - T26E1 Tank

SUBJECT: Control of Gun Fume Hazard



Project No. 41

19 July 1944

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ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 41
File 724-41 SPMEA

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1. PROJECT No. 41 - Physiological Characteristics of the T25E1-T26E1 Tank. First Partial Report; Subject: Control of Gun Fume Hazard.

a. Authority - 2nd Ind. by Office of The Surgeon General to letter, Office of Chief of Ordnance, Washington, D.C. File 00470.8/1442 SPOTT dated 14 June 1944. Subject: Service Test of Medium Tank T25E1 by Armored Medical Research Laboratory.

b. Purpose - To determine the extent of the hazard from fumes released by firing of the weapons in the subject tanks.

2. DISCUSSION:

a. Methods and conditions of test

(1) Fire pattern:

(a) 90 mm gun: The piece was fired at the rate of one (1) round every 10 seconds in bursts of 5. Two such bursts were fired at 5 minute intervals in each test.

(b) Machine Guns: Two belts of 250 rounds each were fired in each test. The rate of fire was approximately 60 rounds per minute, slightly less than 1 minute being required to change belts. Total time of each test was approximately 10 minutes.

(2) Ammunition: 90 mm, shell HE M71 with fuse M43A3; machine gun, caliber .30 ball.

(3) Tank Operation: Tests were conducted with the tank completely closed and with one and both turret hatches open.

(4) Analysis: Air samples from the loader's position were continuously analyzed for carbon monoxide by MSA and IR instruments, checked in certain of the tests by standard chemical methods. In a limited number of tests samples were also collected at other crew positions.

(5) Methods of Ventilation: The subject tank was provided originally (T25E1) with a positive-pressure system of ventilation, employing a Rotoclone fan located in the

bow compartment. This fan had a reported capacity of 275 cfm. With the bulkhead closed off and the tank buttoned-up, this fan was intended to produce and maintain sufficient positive pressure within the vehicle to force gun fumes out the barrel and so prevent internal contamination. Owing to deficiencies in this system, final tests were conducted with a substitute fan (T26E1) having a reported capacity of approximately 1000 cfm. This was an axial-flow fan in contrast to the dust-precipitating fan originally installed.

b. Details of test procedures and results are given in the Appendix.

3. CONCLUSIONS:

a. The original ventilating system was found to provide inadequate control of gun fumes. This was true with the turret hatches open as well as with the tank completely closed.

b. The static pressure and air volume provided by the 1000 cfm fan were found to give adequate control of gun fumes from the 90 mm gun and the two machine guns, with the tank completely buttoned-up or with one or both turret hatches open.

c. Adequate control of gun fumes was had with the 1000 cfm fan even when a 4-3/8" port in the rear turret deck was open.

d. Control of gun fumes was inadequate with both turret hatches open, bulkhead door removed and tank engine operating at idling speed and with ventilating fan off.

4. RECOMMENDATIONS:

a. That a system of positive-pressure ventilation having the characteristics listed below be considered adequate for control of the gun fume hazard in the T 25E1 and T 26E1 tanks:

Capacity - not less than 1000 cfm.

Static pressure (all hatches closed, 90 mm gun breech open)--not less than 0.7 inches, water gage.

NOTE: The foregoing pertains only to control of gun fumes. Further observations are required to determine the acceptability of the proposed system of ventilation from the standpoint of dust and the control of heat in jungle operations.

(NOTE: The conclusions and recommendations set forth above have been concurred in by Headquarters, Armored Center, W. H. Nutter, Colonel, G. S. C., Chief of Staff)

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Incl #2 Figure 1

# APPENDIX

The T25E1 and T26E1 tanks differ from the M4 series vehicles with respect to crew compartment ventilation, in that a system of positive-pressure ventilation is employed. Moreover, instead of being an adjunct to the engine cooling facility, the crew compartment ventilation is independent and operates at constant capacity regardless of engine speed. The bulkhead between the two compartments is closed. The positive-pressure system has the advantage that, since it is installed entirely for the benefit of the crew, it can and should be designed in terms of the crew requirements. From the standpoint of control of gun fumes, the action of the positive-pressure system is basically different from that of the negative-pressure system in the M4 series tanks. The success of the latter depends largely upon the volume of air flow for dilution of the fumes and, hence, varies in effectiveness with engine speed. With positive-pressure ventilation, the bulk of gun fumes should be forced out the barrel immediately upon opening the breech, leaving only the gases trapped in the shell casing for removal by dilution in the ventilating air. Since, however, the guns are fired with hatches open (no positive-pressure) as well as closed, the rate of ventilation must also be sufficient to dilute and remove the fumes at such times. A certain minimum positive-pressure in the closed vehicle is therefore not enough; the capacity of the system must be great enough to meet the volume flow requirements as well.

## RESULTS OF TESTS

a. With original fan. Tests with the 90 mm gun were conducted under the following conditions:

(1) Tank buttoned-up, fan on, engine idling

(2) Commander's hatch, only, open, fan on, engine idling

(3) Both turret hatches open, fan on, engine idling

(4) Both turret hatches open, fan off, engine idling

The results are summarized in Table 1, with respect to gas concentrations.



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TABLE 1

AVERAGE CARBON MONOXIDE CONCENTRATIONS DURING FIRING OF THE 90 MM GUN, IN THE T25E1

(All Tabulated values were determined with the Infra-red CO recorder except where otherwise noted)

| Conditions of Test | | | | CARBON MONOXIDE AVERAGE CONCENTRATION Percent | | |
|---|---|---|---|---|---|---|
| No. | Engine | Hatches | Fan | Loader | Commander | Asst.Driver |
| 1 | Idling | Closed | On | .180 | .143 g | .040 g |
| 2 | Idling | Comm Open | On | .153 | .086 g | -- |
| 3 | Idling | Both Turret open | On | .139 | .098 g | -- |
| 4 | Idling | Both Turret open | Off | .170 | — | -- |

Note: The values followed by 'g' were obtained by chemical analysis of continuous samples collected in flasks.

In comparison with the permissible upper limit of carbon monoxide of 0.05% concentrations, it is evident that the control of gun fumes was entirely inadequate under any of these test conditions. This conclusion is also borne out by the reports of all turret crew members to the effect that they experienced considerable eye and throat irritation during these tests. The positive-pressure developed by the original fan was only 0.06 inches, water gage. It was later discovered that there was serious air leakage around improperly sealed escape hatches and bulkhead door. To a degree this invalidates this test for adequacy of the positive-pressure provided by the system. The point is unimportant, however, in view of the results obtained in tests 2 and 3 with turret hatches open. In these the unsatisfactory conditions are attributable entirely to inadequate rate of ventilation. The result was incomplete clearing of the turret after each round was fired with consequent accumulation of toxic and irritating gases. These findings point clearly to the necessity for a greater rate of ventilation. With the higher rate of air flow, the problem of maintaining sufficient pressure in the closed vehicle is thereby made easier.

Results of tests with the two machine guns are summarized in Table 2, with the test conditions noted. The findings indicate that no hazard existed in the firing of these weapons.



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TABLE 2

AVERAGE CARBON MONOXIDE CONCENTRATION DURING
FIRING OF THE MACHINE GUNS IN THE T25E1

| Conditions of Test | | | | CARBON MONOXIDE AVERAGE CONCENTRATION Percent |
|---|---|---|---|---|
| No. | Engine | Hatches | Fan | |
| Coaxial M. G. | | | | Loader |
| 1. | Idling | Closed | On | < .01 |
| 2. | Idling | Both Turret Open | On | < .01 |
| Bow M. T. | | | | Bow Gunner |
| 1. | Idling | closed | On | < .01 |
| 2. | Idling | closed | Off | .034 |

b. With new fan of 1000 cfm capacity. Following the tests described above, a larger fan was provided by Ordnance for test. This fan, having a reported capacity of approximately 1000 cfm, was installed in a T26E1 Tank by the Armored Board in place of the original Rotoclone, making use of the same air inlet in the roof of the bow compartment. It was of the axial-flow type and therefore provided no facility for dust precipitation. Prior to test the escape hatches and the bulkhead door were properly sealed and for experimental purposes a port 4-3/8" dia. was cut in the extreme rear of the turret roof. With the tank completely closed, the following static pressures were obtained:

| | |
|---|---|
| 90 mm gun breech closed, experimental port closed | 1.9 ins. |
| 90 mm gun breech open, experimental port closed | 1.4 " |
| 90 mm gun breech closed, port open | 1.0 " |
| 90 mm gun breech open, port open | 0.7 ins. |

These pressures are of particular interest in view of the fact that in previous tests with the 75 mm gun, a static pressure of 0.5 ins. had been found sufficient to force gun fumes out the barrel.

Tests with the 90 mm gun were conducted under the following conditions,

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all with tank engine off, and with new ventilating fan in operation.

(1) Tank buttoned-up, experimental port closed

(2) Tank buttoned up, experimental port open

(3) Commander's hatch, only, open

(4) Both turret hatches open

In addition, one test (5) was run with the ventilating fan off, both turret hatches open, bulkhead door open and tank engine operating at idling speed. The purpose of this test was to determine the effectiveness of negative ventilation of the crew compartment by means of engine cooling air. No measurements were made of the rate of crew compartment ventilation obtained by this means. It is known, however, to be less than in the M4 tanks, owing to the lesser resistance to air flow through the outside air grille.

The results of tests with the 90 mm gun are summarized in Table 3 and the carbon monoxide concentrations are compared in Fig. 1 with results obtained with the original fan under similar conditions of operation.

TABLE 3

AVERAGE CARBON MONOXIDE CONCENTRATIONS AT THE LOADER'S BREATHING ZONE DURING FIRING OF THE 90 MM GUN IN THE T26E1

| Conditions of Test | | | | | | CARBON MONOXIDE AVERAGE CONCENTRATION Percent |
|---|---|---|---|---|---|---|
| No. | Engine | Hatches | Fan | Exp. Port | Bulkhead | |
| 1 | Off | Closed | On | Closed | Closed | < .01 |
| 2 | Off | Closed | On | Open | Closed | < .015 |
| 3 | Off | Com. Open | On | Open | Closed | < .01 |
| 4. | Off | Both Turret Open | On | Open | Closed | < .01 |
| 5. | Idling | Both Turret Open | Off | Closed | Open | .023 |

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The improvement gained by the greater pressure and rate of air flow is striking and it is evident that the carbon monoxide concentration has been reduced to levels well within the acceptable limit of 0.05%. Reports of the crew were equally favorable, with no eye or throat irritation observed except momentarily at the Commander's position immediately after a round was fired. The rate of clearance was so high that all evidence of smoke disappeared almost immediately after the fifth round of a burst was fired. Residual smoke from the empty shell casings was noted but it appeared to be coming from the outside of the casings.

The results obtained with the tank engine in operation, bulkhead door open and ventilating fan off are recorded at the bottom of Table 3. The carbon monoxide concentration was somewhat higher than with the ventilating fan in use. The deterioration of the turret atmosphere was actually much greater, however, than is indicated by the increase in CO concentration at the loader's position. At both commander's and gunner's positions the atmosphere became very irritating and after firing the third round in a burst the gunner was unable to see through his sight because of the high ammonia concentration. It is evident that this method of ventilation is not adequate and should not be considered as a control measure.

Practically immeasurable carbon monoxide concentrations were obtained from firing the turret or bow machine guns, as noted in Table 4.

TABLE 4

AVERAGE CARBON MONOXIDE CONCENTRATIONS DURING FIRING OF THE MACHINE GUNS IN THE T26E1

| Conditions of Test | | | | | | CARBON MONOXIDE AVERAGE CONCENTRATION Percent |
|---|---|---|---|---|---|---|
| No. | Engine | Hatches | Fan | Exp. Port | Bulkhead | |
| Coaxial M. G. | | | | | | Loader |
| 1. | Off | Closed | On | Open | Closed | < .01 |
| 2. | Off | Comm. Open | On | Open | Closed | < .015 |
| Bow M.G. | | | | | | Bow Gunner |
| 1. | Off | Closed | On | Open | Closed | < .01 |



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SUMMARY

The results of these tests are clear-cut and require little discussion. The inadequacy of the original ventilating system is clearly demonstrated. It is equally well shown, however, that the new fan with its greater capacity and the consequent higher static pressure within the tank provides an effective method of controlling the gun fume hazard. No advantage is seen in the additional port in the rear turret roof and no special port is recommended so long as the sealing of the joints in the turret openings is not made more effective. If further improvement in seals is contemplated, an escape port may be required to keep the pressure from going too high, in which case it should be located in the turret roof above the gun rather than in the rear.

During the course of tests with the new fan, noticeable amounts of dust were drawn into the tank immediately after the gun was fired, the blast from which produced a dense dust cloud. This indicates the need for investigating the dust problem associated with the proposed ventilating system before final acceptance. Another problem requiring study is one of heat removal in jungle operations. In earlier reports attention has been called to this problem, and the need for adequate ventilation to prevent serious deterioration of the tank atmosphere pointed out. From the standpoint of rate of ventilation, the positive-pressure system differs from that provided in the M4 tank in that the rate remains constant at 1000 cfm regardless of engine speed. With the tank engine idling, the rate of air flow through the crew compartment in the M4A3 tank is only 300 cfm. The present tank, therefore, has superior ventilation when the tank is stationary. At normal cruising speed, however, the rate of ventilation in the M4A3 is 2000 cfm or more. This higher rate is believed to be adequate for jungle operations but reports from combat areas in the Pacific theaters indicate that the ventilation provided with the engine idling is not sufficient to control heat inside the vehicle. It remains to be determined whether or not a rate of ventilation of 1000 cfm is adequate. The proposed method of positive ventilation of the T26E1 tank at 1000 cfm will receive immediate study from the standpoint of the dust and heat problems. Until this is done, conclusions with reference to it are limited to its effectiveness as a means of controlling gun fumes.



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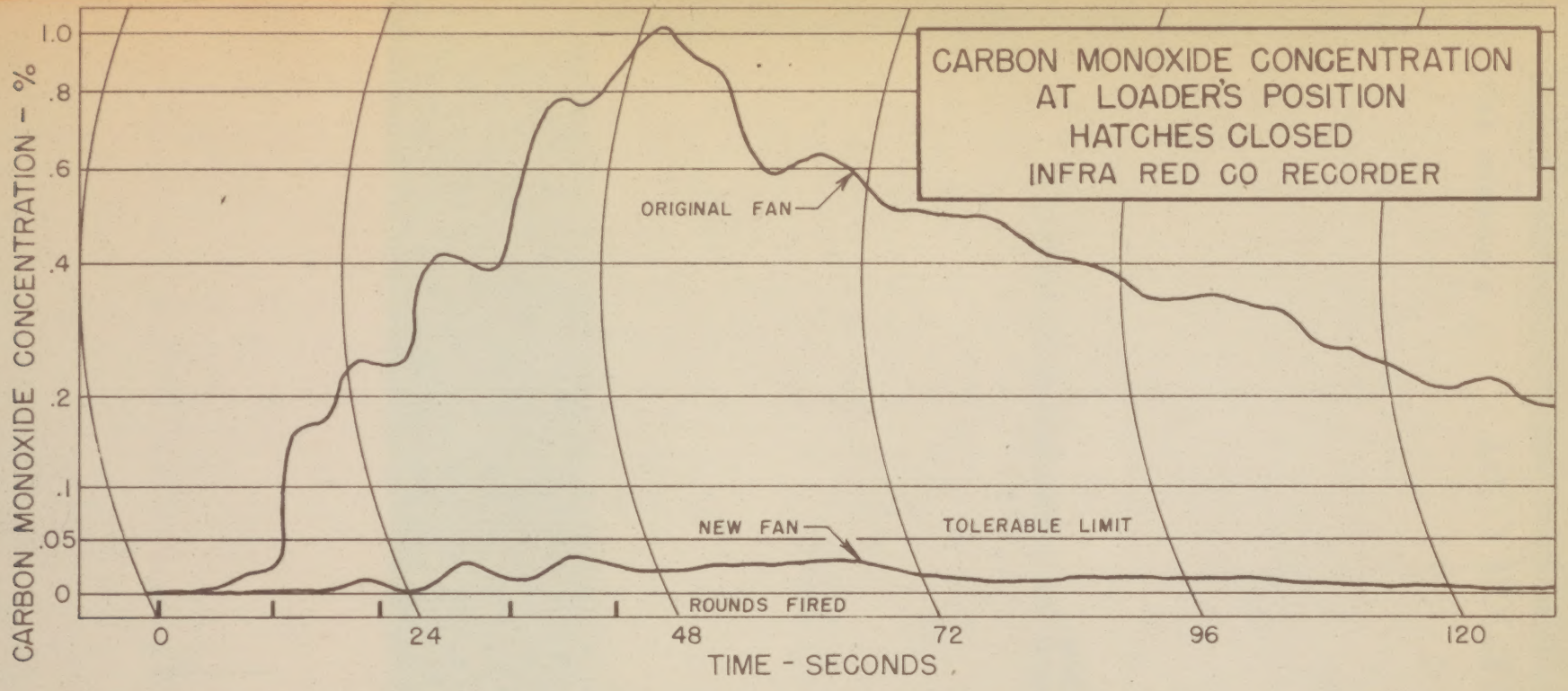
CARBON MONOXIDE CONCENTRATION AT LOADER'S POSITION
HATCHES CLOSED
INFRA RED CO RECORDER
CARBON MONOXIDE CONCENTRATION - %
1.0
.8
.6
.4
.2
.1
.05
0
ORIGINAL FAN
NEW FAN
TOLERABLE LIMIT
ROUNDS FIRED
0
24
48
72
96
120
TIME - SECONDS

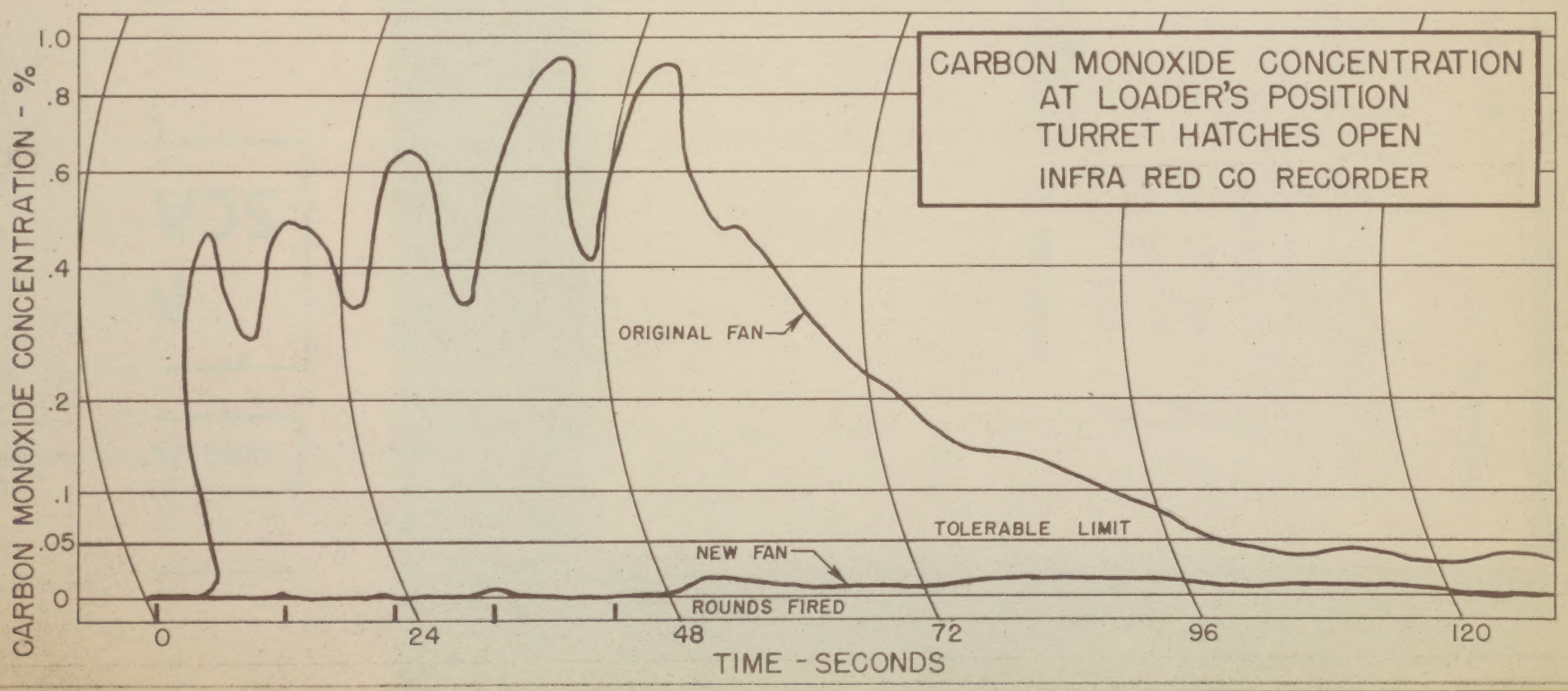
CARBON MONOXIDE CONCENTRATION AT LOADER'S POSITION
TURRET HATCHES OPEN
INFRA RED CO RECORDER
CARBON MONOXIDE CONCENTRATION - %
1.0
.8
.6
.4
.2
.1
.05
0
ORIGINAL FAN
TOLERABLE LIMIT
NEW FAN
ROUNDS FIRED
0
24
48
72
96
120
TIME - SECONDS

FIG. 1

Sheet #2